

7-Azaindoles and the use thereof as therapeutic agents

Description

5 The invention relates to substituted 7-azaindoles, process for their preparation, pharmaceutical preparations which comprise these compounds, and the pharmaceutical use of these compounds, which are inhibitors of phosphodiesterase 4, as active
10 ingredients for the treatment of disorders which can be influenced by inhibition of phosphodiesterase 4 activity in particular in immunocompetent cells (e.g. macrophages and lymphocytes) by the compounds of the invention.

15. Activation of cell membrane receptors by transmitters leads to activation of the second messenger system. Adenylate cyclase synthesizes the active cyclic AMP (cAMP) and cyclic GMP (cGMP) respectively from AMP and
20 GMP. cAMP and cGMP lead for example in smooth muscle cells to relaxation, and in inflammatory cells to inhibition of mediator release and synthesis. The second messengers cAMP and cGMP are degraded by phosphodiesterases (PDE). To date, 11 families of PDE
25 enzymes (PDE1-11) are known and differ through their substrate specificity (cAMP, cGMP or both) and the dependence on other substrates (e.g. calmodulin). These isoenzymes have different functions in the body and are expressed differently in individual cell types (Beavo,
30 J.A., Conti, M. and Heasley, R.J., Multiple cyclic nucleotide phosphodiesterases. Mol. Pharmacol. 1994, 46:399-405; Hall, I.P., Isoenzyme selective phosphodiesterase inhibitors: potential clinical uses, Br. J. clin. Pharmacol. 1993, 35:1-7). Inhibition of
35 the various PDE isoenzyme types results in accumulation of cAMP or cGMP in cells, which can be utilized therapeutically (Torphy, T.J., Livi, G.P., Christensen, S.B. Novel Phosphodiesterase Inhibitors for the Therapy of Asthma, Drug News and Perspectives 1993, 6:203-214).

The predominant PDE-isoenzyme in cells important for allergic inflammations (lymphocytes, mast cells, eosinophilic granulocytes, macrophages) is that of type 4 (Torphy, J. T. and Undem, B. J., Phosphodiesterase inhibitors: new opportunities for the treatment of asthma. Thorax 1991, 46:512-523). Inhibition of PDE 4 by suitable inhibitors is therefore regarded as an important approach to the therapy of a large number of allergically induced disorders (Schudt, Ch., Dent, G., Rabe, K, Phosphodiesterase Inhibitors, Academic Press London 1996).

An important property of phosphodiesterase 4 inhibitors is inhibition of the release of tumor necrosis factor α (TNF α) from inflammatory cells. TNF α is an important proinflammatory cytokine which influences a large number of biological processes. TNF α is released for example from activated macrophages, activated T lymphocytes, mast cells, basophils, fibroblasts, endothelial cells and astrocytes in the brain. It has itself an activating effect on neutrophils, eosinophils, fibroblasts and endothelial cells, whereby various tissue-damaging mediators are released. The effect of TNF α in monocytes, macrophages and T lymphocytes is increased production of further proinflammatory cytokines such as GM-CSF (granulocyte-macrophage colony-stimulating factor) or interleukin-8. Owing to its proinflammatory and catabolic effect, TNF α plays a central role in a large number of disorders such as inflammations of the respiratory tract, inflammations of the joints, endotoxic shock, tissue rejections, AIDS and many other immunological disorders. Thus, phosphodiesterase 4 inhibitors are likewise suitable for the therapy of such disorders associated with TNF α .

Chronic obstructive pulmonary diseases (COPD) are widespread in the population and also have great

economic importance. Thus, COPD disorders are the cause of about 10-15% of all illness costs in the developed countries, and about 25% of all deaths in the USA are attributable to this cause (Norman, P.: COPD: New
5 developments and therapeutic opportunities, Drug News Perspect. 11 (7), 431-437, 1998). The WHO estimates that COPD will become the third-commonest cause of death in the next 20 years.

10 The pathological condition of chronic obstructive pulmonary diseases (COPD) encompasses various pathological conditions of chronic bronchitis with the symptoms of coughing and expectoration, and progressive and irreversible deterioration in lung function
15 (expiration is particularly affected). The course of the disease is episodic and often complicated by bacterial infections (Rennard, S. I.: COPD: Overview of definitions, Epidemiology, and factors influencing its development. Chest, 113 (4) Suppl., 235S-241S, 1998).
20 There is a steady decline in lung function during the disorder, the lung becomes increasingly emphysematous, and the patients' breathing difficulty becomes obvious. This disorder markedly impairs the patients' quality of life (shortness of breath, low exercise tolerance) and
25 significantly shortens their life expectancy. Besides environmental factors, the main risk factor is smoking (Kummer, F.: Asthma and COPD. Atemw.-Lungenkrkh. 20 (5), 299-302, 1994; Rennard, S. I.: COPD: Overview of definitions, Epidemiology, and factors influencing its
30 development. Chest, 113 (4) Suppl., 235S-241S, 1998) and thus men are affected distinctly more frequently than are women. However, this picture will change in the future due to the alteration in lifestyles and the increase in the number of female smokers.

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Current therapy claims only to alleviate the symptoms without affecting the causes of the progression of the disorder. The use of long-acting beta2 agonists (e.g. salmeterol), possibly in combination with muscarinergic

antagonists (e.g. ipratropium), improves lung function through bronchodilatation and is routinely employed (Norman, P.: COPD: New developments and therapeutic opportunities, Drug News Perspect. 11 (7), 431-437, 1998). Bacterial infections play a large part in the episodes of COPD and need antibiotic treatment (Wilson, R.: The role of infection in COPD, Chest, 113 (4) Suppl., 242S-248S, 1998; Grossman, R.F.: The value of antibiotics and the outcomes of antibiotic therapy in exacerbations of COPD. Chest, 113 (4) Suppl., 249S-255S, 1998). Therapy of this disorder is currently unsatisfactory, especially in relation to the continuous decline in lung function. New therapeutic approaches acting on mediators of inflammation, proteases or adhesion molecules might be very promising (Barnes, P.J.: Chronic obstructive disease: new opportunities for drug development, TIPS 10 (19), 415-423, 1998).

Irrespective of the bacterial infections complicating the disorder, a chronic inflammation is found in the bronchi and is dominated by neutrophilic granulocytes. The mediators and enzymes released by neutrophilic granulocytes are thought inter alia to be responsible for the observed structural changes in the respiratory tract (emphysema). Inhibition of the activity of neutrophilic granulocytes is thus a rational approach to the prevention or slowing down of the progression of COPD (deterioration in parameters of lung function). An important stimulus for the activation of granulocytes is the proinflammatory cytokine TNF α (tumor necrosis factor). Thus, it is known that TNF α stimulates the formation of oxygen free radicals by neutrophilic granulocytes (Jersmann, H.P.A.; Rathjen, D.A. and Ferrante, A.: Enhancement of LPS-induced neutrophil oxygen radical production by TNF α , Infection and Immunity, 4, 1744-1747, 1998). PDE4 inhibitors are able to inhibit very effectively the release of TNF α from a large number of cells and thus suppress the activity of

neutrophilic granulocytes. The nonspecific PDE inhibitor pentoxifylline is able to inhibit both the formation of oxygen free radicals and the phagocytic ability of neutrophilic granulocytes (Wenisch, C.; Zedtwitz-Liebenstein, K.; Parschalk, B. and Graninger, W.: Effect of pentoxifylline in vitro on neutrophil reactive oxygen production and phagocytic ability assessed by flow cytometry, Clin. Drug Invest., 13(2):99-104, 1997).

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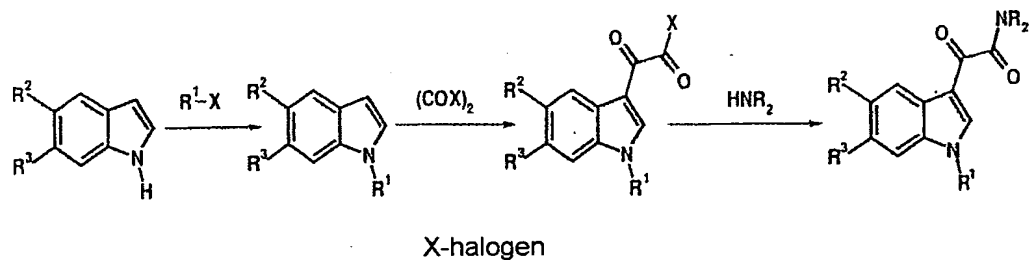
Various PDE 4 inhibitors have already been disclosed. These are primarily xanthine derivatives, rolipram analogs or nitraquazone derivatives (review in: Karlsson, J.A., Aldos, D., Phosphodiesterase 4 inhibitors for the treatment of asthma, Exp. Opin. Ther. Patents 1997, 7: 989-1003). It has not been possible to date for any of these compounds to be used clinically. It was unavoidably found that the known PDE4 inhibitors also have various side effects, such as nausea and emesis, which it has not to date been possible to suppress adequately. It is therefore necessary to discover novel PDE4 inhibitors with improved therapeutic index.

20

25 Indol-3-ylglyoxylamides and processes for preparing them have already been described several times. In all cases, indoles unsubstituted in position 3, which are synthesized by substitution in position 1 of a commercially available indole, were converted by reaction with oxalyl halides into indol-3-ylglyoxyl halides which subsequently afford, by reaction with ammonia or with primary or secondary amines, the corresponding indol-3-ylglyoxylamides. (Scheme 1)

30

Scheme 1:



5 Thus, US patents 2,825,734 and 3,188,313 describe various indol-3-ylglyoxylamides which are prepared by the manner depicted in Scheme 1. These compounds were used as intermediates for preparing indole derivatives produced by reductions. US patent 3,642,803 also
10 describes indol-3-ylglyoxylamides.

The preparation of 5-methoxyindol-3-ylglyoxylamides is described in *Farmaco* 22 (1967), 229-244. Again there is reaction of the indole derivative used with oxalyl
15 chloride, and the resulting indol-3-ylglyoxyl chloride is reacted with an amine.

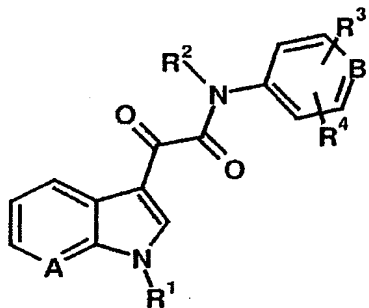
In addition, US patent 6,008,231 describes indol-3-ylglyoxylamides and processes for preparing them. Once
20 again, the reaction steps and conditions depicted in Scheme 1 are used.

Substituted 5-hydroxyindolylglyoxylamides and 6-hydroxyindolylglyoxylamides and processes for preparing
25 them and the use thereof as PDE4 inhibitors were described for the first time in DE patent application 198 18 964 A1.

7-Azaindol-3-ylglyoxylamides are disclosed as PDE4
30 inhibitors in DE patent application 100 53 275 A1, which also describes their preparation and use as therapeutic agents.

4- and 7-Hydroxyindole derivatives, their preparation and use as PDE4 inhibitors are proposed in DE patent application 102 53 426.8.

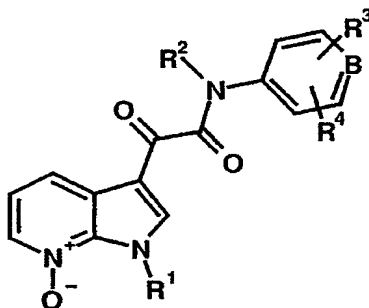
- 5 The invention relates to substituted 7-azaindoles of the general formula 1



- 10 and the physiologically tolerated salts thereof.

The compounds of the invention preferably include compounds of the formula 1 in which

- 15 **A** is an N-oxide group and **B** is carbon (i.e. a CH group or a group CR³ as defined below) or nitrogen. These are the compounds of the invention of the formula 1a



- 20 in which

R¹

- (i) is -C₁₋₁₀-alkyl, straight-chain or branched-chain, optionally mono- or polysubstituted by
- 25

- 5 -OH, -SH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NHC₆₋₁₄-aryl, -N(C₆₋₁₄-aryl)₂, -N(C₁₋₆-alkyl)(C₆₋₁₄-aryl), -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -O-C₆₋₁₄-aryl, -S-C₁₋₆-alkyl, -S-C₆₋₁₄-aryl, -SO₃H, -SO₂C₁₋₆-alkyl, -SO₂C₆₋₁₄-aryl, -OSO₂C₁₋₆-alkyl, -OSO₂C₆₋₁₄-aryl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl, -O(CO)C₁₋₅-alkyl, by mono-, bi- or tricyclic saturated or mono- or polyunsaturated carbocycles with 3-14 ring members or/and by mono-, bi- or tricyclic saturated or mono- or polyunsaturated heterocycles with 5-15 ring members and 1-6 heteroatoms, which are preferably N, O and S, where the C₆₋₁₄-aryl groups and the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by -C₁₋₆-alkyl, -OH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -S-C₁₋₆-alkyl, -SO₃H, -SO₂C₁₋₆-alkyl, -OSO₂C₁₋₆-alkyl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl or/and -O(CO)C₁₋₅-alkyl, and where the alkyl groups on the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H or/and -COOH, or
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- 25
- (ii) is -C₂₋₁₀-alkenyl, mono- or polyunsaturated, straight-chain or branched-chain, optionally mono- or polysubstituted by -OH, -SH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NHC₆₋₁₄-aryl, -N(C₆₋₁₄-aryl)₂, -N(C₁₋₆-alkyl)(C₆₋₁₄-aryl), -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -O-C₆₋₁₄-aryl, -S-C₁₋₆-alkyl, -S-C₆₋₁₄-aryl, -SO₃H, -SO₂C₁₋₆-alkyl, -SO₂C₆₋₁₄-aryl, -OSO₂C₁₋₆-alkyl, -OSO₂C₆₋₁₄-aryl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl or/and -O(CO)C₁₋₅-alkyl, by mono-, bi- or tricyclic saturated or mono- or polyunsaturated carbocycles with 3-14 ring members or/and by mono-, bi- or tricyclic saturated or mono- or
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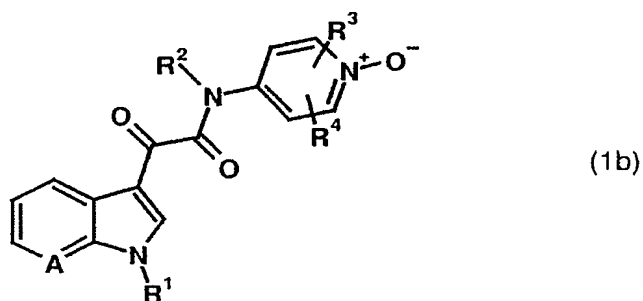
polyunsaturated heterocycles with 5-15 ring members and 1-6 heteroatoms, which are preferably N, O and S, where the C₆₋₁₄-aryl groups and the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by -C₁₋₆-alkyl, -OH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -S-C₁₋₆-alkyl, -SO₃H, -SO₂C₁₋₆-alkyl, -OSO₂C₁₋₆-alkyl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl or/and -O(CO)C₁₋₅-alkyl, and where the alkyl groups on the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H or/and -COOH,

R² is hydrogen or -C₁₋₃-alkyl,

R³ and R⁴ may be identical or different and are hydrogen, -C₁₋₆-alkyl, -OH, -SH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NO₂, -CN, -SO₃H, -SO₃-C₁₋₆-alkyl, -COOH, -COO-C₁₋₆-alkyl, -O(CO)-C₁₋₅-alkyl, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -S-C₁₋₆-alkyl, -phenyl or -pyridyl, where the phenyl or pyridyl substituents in turn may optionally be substituted one or more times by -C₁₋₃-alkyl, -OH, -SH, -NH₂, -NHC₁₋₃-alkyl, -N(C₁₋₃-alkyl)₂, -NO₂, -CN, -SO₃H, -SO₃C₁₋₃-alkyl, -COOH, -COOC₁₋₃-alkyl, -F, -Cl, -Br, -I, -O-C₁₋₃-alkyl, -S-C₁₋₃-alkyl, or/and -O(CO)C₁₋₃-alkyl, and where the alkyl substituents in turn may optionally be substituted one or more times by -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H, -SO₃C₁₋₃-alkyl, -COOH, -COOC₁₋₃-alkyl, -O-C₁₋₃-alkyl, -S-C₁₋₃-alkyl or/and -O(CO)-C₁₋₃-alkyl.

The compounds of the invention additionally preferably include N-oxides of the formula 1 in which

B is an N-oxide group. These are the compounds of the invention of the formula 1b



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in which
A is nitrogen,

R^1

- 10 (i) is $-C_{1-10}$ -alkyl, straight-chain or branched-chain, optionally mono- or polysubstituted by
- 15 $-OH$, $-SH$, $-NH_2$, $-NHC_{1-6}$ -alkyl, $-N(C_{1-6}$ -alkyl) $_2$, $-NHC_{6-14}$ -aryl, $-N(C_{6-14}$ -aryl) $_2$, $-N(C_{1-6}$ -alkyl)(C_{6-14} -aryl), $-NO_2$, $-CN$, $-F$, $-Cl$, $-Br$, $-I$, $-O-C_{1-6}$ -alkyl, $-O-C_{6-14}$ -aryl, $-S-C_{1-6}$ -alkyl, $-S-C_{6-14}$ -aryl, $-SO_3H$, $-SO_2C_{1-6}$ -alkyl, $-SO_2C_{6-14}$ -aryl, $-OSO_2C_{1-6}$ -alkyl, $-OSO_2C_{6-14}$ -aryl, $-COOH$, $-(CO)C_{15}$ -alkyl, $-COO-C_{1-5}$ -alkyl, $-O(CO)C_{1-5}$ -alkyl, by mono-, bi- or tricyclic saturated or mono- or
- 20 polyunsaturated carbocycles with 3-14 ring members or/and by mono-, bi- or tricyclic saturated or mono- or polyunsaturated heterocycles with 5-15 ring members and 1-6 heteroatoms, which are preferably N, O and S,
- 25 where the C_{6-14} -aryl groups and the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by $-C_{1-6}$ -alkyl, $-OH$, $-NH_2$, $-NHC_{1-6}$ -alkyl, $-N(C_{1-6}$ -alkyl) $_2$, $-NO_2$, $-CN$, $-F$, $-Cl$, $-Br$, $-I$, $-O-C_{1-6}$ -alkyl, $-S-C_{1-6}$ -alkyl, $-SO_3H$, $-SO_2C_{1-6}$ -alkyl, $-OSO_2C_{1-6}$ -alkyl, $-COOH$, $-(CO)C_{1-5}$ -alkyl, $-COO-C_{1-5}$ -alkyl or/and $-O(CO)C_{1-5}$ -alkyl, and where the
- 30 alkyl groups on the carbocyclic and

heterocyclic substituents in turn may optionally be substituted one or more times by -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H or/and -COOH, or

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- (ii) is -C₂₋₁₀-alkenyl, mono- or polyunsaturated, straight-chain or branched-chain, optionally mono- or polysubstituted by -OH, -SH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NHC₆₋₁₄-aryl, -N(C₆₋₁₄-aryl)₂, -N(C₁₋₆-alkyl)(C₆₋₁₄-aryl), -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -O-C₆₋₁₄-aryl, -S-C₁₋₆-alkyl, -S-C₆₋₁₄-aryl, -SO₃H, -SO₂C₁₋₆-alkyl, -SO₂C₆₋₁₄-aryl, -OSO₂C₁₋₆-alkyl, -OSO₂C₆₋₁₄-aryl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl, -O(CO)C₁₋₅-alkyl, by mono-, bi- or tricyclic saturated or mono- or polyunsaturated carbocycles with 3-14 ring members or/and by mono-, bi- or tricyclic saturated or mono- or polyunsaturated heterocycles with 5-15 ring members and 1-6 heteroatoms, which are preferably N, O and S, where the C₆₋₁₄-aryl groups and the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by -C₁₋₆-alkyl-OH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -S-C₁₋₆-alkyl, -SO₃H, -SO₂C₁₋₆-alkyl, -OSO₂C₁₋₆-alkyl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl or/and -O(CO)C₁₋₅-alkyl, and where the alkyl groups on the carbocyclic and heterocyclic substituents in turn may optionally be substituted one or more times by -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H or/and -COOH,

R² is hydrogen or -C₁₋₃-alkyl,

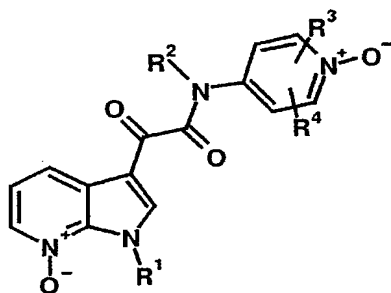
R³ and R⁴ may be identical or different and are

hydrogen, $-C_{1-6}$ -alkyl, $-OH$, $-SH$, $-NH_2$, $-NHC_{1-6}$ -alkyl, $-N(C_{1-6}$ -alkyl) $_2$, $-NO_2$, $-CN$, $-SO_3H$, $-SO_3-C_{1-6}$ -alkyl, $-COOH$, $-COO-C_{1-6}$ -alkyl, $-O(CO)-C_{1-5}$ -alkyl, $-F$, $-Cl$, $-Br$, $-I$, $-O-C_{1-6}$ -alkyl, $-S-C_{1-6}$ -alkyl, $-phenyl$ or $-pyridyl$, where the
 5 phenyl or pyridyl substituents in turn may optionally be substituted one or more times by $-C_{1-3}$ -alkyl, $-OH$, $-SH$, $-NH_2$, $-NHC_{1-3}$ -alkyl, $-N(C_{1-3}$ -alkyl) $_2$, $-NO_2$, $-CN$, $-COOH$, $-SO_3H$, $-SO_3C_{1-3}$ -alkyl, $-COOC_{1-3}$ -alkyl, $-F$, $-Cl$, $-Br$, $-I$, $-O-C_{1-3}$ -alkyl, $-S-C_{1-3}$ -alkyl or/and $-O(CO)-C_{1-3}$ -
 10 alkyl, and where alkyl substituents in turn may optionally be substituted one or more times by $-OH$, $-SH$, $-NH_2$, $-F$, $-Cl$, $-Br$, $-I$, $-SO_3H$, $-SO_3C_{1-3}$ -alkyl, $-COOH$, $-COOC_{1-3}$ -alkyl, $-O-C_{1-3}$ -alkyl, $-S-C_{1-3}$ -alkyl or/and $-O(CO)-C_{1-3}$ -alkyl.

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The compounds of the invention additionally include N-oxides of the formula 1 in which

A and **B** are an N-oxide group. These are the compounds
 20 of the invention of the formula 1c



(1c)

in which

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R^1

(i) is $-C_{1-10}$ -alkyl, straight-chain or branched-chain, optionally mono- or polysubstituted by $-OH$, $-SH$, $-NH_2$, $-NHC_{1-6}$ -alkyl, $-N(C_{1-6}$ -alkyl) $_2$, $-NHC_{6-14}$ -aryl, $-N(C_{6-14}$ -aryl) $_2$, $-N(C_{1-6}$ -alkyl)(C_{6-14} -aryl), $-NO_2$, $-CN$, $-F$, $-Cl$, $-Br$, $-I$, $-O-C_{1-6}$ -alkyl, $-O-C_{6-14}$ -aryl, $-S-C_{1-6}$ -alkyl, $-S-C_{6-14}$ -aryl, $-SO_3H$, $-SO_2C_{1-6}$ -alkyl, $-SO_2C_{6-14}$ -aryl, $-OSO_2C_{1-6}$ -alkyl, $-OSO_2C_{6-14}$ -aryl, $-COOH$, $-(CO)C_{15}$ -alkyl,

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5 -COO-C₁₋₅-alkyl, -O(CO)C₁₋₅-alkyl, by mono-, bi-
 or tricyclic saturated or mono- or
 polyunsaturated carbocycles with 3-14 ring
 members or/and by mono-, bi- or tricyclic
 10 saturated or mono- or polyunsaturated
 heterocycles with 5-15 ring members and 1-6
 heteroatoms, which are preferably N, O and S,
 where the C₆₋₁₄-aryl groups and the carbocyclic
 and heterocyclic substituents in turn may
 15 optionally be substituted one or more times by
 -C₁₋₆-alkyl, -OH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-
 alkyl)₂, -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-
 alkyl, -S-C₁₋₆-alkyl, -SO₃H, -SO₂C₁₋₆-alkyl,
 -OSO₂C₁₋₆-alkyl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-
 20 alkyl or/and -O(CO)C₁₋₅-alkyl, and where the
 alkyl groups on the carbocyclic and
 heterocyclic substituents in turn may
 optionally be substituted one or more times by
 -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H or/and
 -COOH, or

(ii) is -C₂₋₁₀-alkenyl, mono- or polyunsaturated,
 straight-chain or branched-chain, optionally
 mono- or polysubstituted by -OH, -SH, -NH₂,
 25 -NHC₁₋₆-alkyl, -N(C₁₋₆-alkyl)₂, -NHC₆₋₁₄-aryl,
 -N(C₆₋₁₄-aryl)₂, -N(C₁₋₆-alkyl)(C₆₋₁₄-aryl), -NO₂,
 -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-alkyl, -O-C₆₋₁₄-
 aryl, -S-C₁₋₆-alkyl, -S-C₆₋₁₄-aryl, -SO₃H,
 -SO₂C₁₋₆-alkyl, -SO₂C₆₋₁₄-aryl, -OSO₂C₁₋₆-alkyl,
 30 -OSO₂C₆₋₁₄-aryl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-
 alkyl, -O(CO)C₁₋₅-alkyl, by mono-, bi- or
 tricyclic saturated or mono- or polyunsaturated
 carbocycles with 3-14 ring members or/and by
 mono-, bi- or tricyclic saturated or mono- or
 35 polyunsaturated heterocycles with 5-15 ring
 members and 1-6 heteroatoms, which are
 preferably N, O and S,
 where the C₆₋₁₄-aryl groups and the carbocyclic
 and heterocyclic substituents in turn may

optionally be substituted one or more times by
-C₁₋₆-alkyl, -OH, -NH₂, -NHC₁₋₆-alkyl, -N(C₁₋₆-
alkyl)₂, -NO₂, -CN, -F, -Cl, -Br, -I, -O-C₁₋₆-
alkyl, -S-C₁₋₆-alkyl, -SO₃H, -SO₂C₁₋₆-alkyl,
5 -OSO₂C₁₋₆-alkyl, -COOH, -(CO)C₁₋₅-alkyl, -COO-C₁₋₅-alkyl or/and -O(CO)C₁₋₅-alkyl, and where the
alkyl groups on the carbocyclic and
heterocyclic substituents in turn may
optionally be substituted one or more times by
10 -OH, -SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H or/and
-COOH,

R² is hydrogen or -C₁₋₃-alkyl,

15 R³ and R⁴ may be identical or different and are
hydrogen, -C₁₋₆-alkyl, -OH, -SH, -NH₂, -NHC₁₋₆-alkyl,
-N(C₁₋₆-alkyl)₂, -NO₂, -CN, -SO₃H, -SO₃-C₁₋₆-alkyl, -COOH,
-COO-C₁₋₆-alkyl, -O(CO)-C₁₋₅-alkyl, -F, -Cl, -Br, -I, -O-
C₁₋₆-alkyl, -S-C₁₋₆-alkyl, -phenyl or -pyridyl, where the
20 phenyl or pyridyl substituents in turn may optionally
be substituted one or more times by -C₁₋₃-alkyl, -OH,
-SH, -NH₂, -NHC₁₋₃-alkyl, -N(C₁₋₃-alkyl)₂, -NO₂, -CN,
-SO₃H, -SO₃C₁₋₃-alkyl, -COOH, -COOC₁₋₃-alkyl, -F, -Cl,
-Br, -I, -O-C₁₋₃-alkyl, -S-C₁₋₃-alkyl or/and -O(CO)C₁₋₃-
25 alkyl, and where the alkyl substituents in turn may
optionally be substituted one or more times by -OH,
-SH, -NH₂, -F, -Cl, -Br, -I, -SO₃H, -SO₃C₁₋₃-alkyl,
-COOH, -COOC₁₋₃-alkyl, -O-C₁₋₃-alkyl, -S-C₁₋₃-alkyl or/and
-O(CO)-C₁₋₃-alkyl.

30

Preferred compounds of the formula 1 are those in which
R¹ is an optionally substituted C₁₋₄-alkyl radical,
particularly preferably a C₁ radical, with a cyclic
substituent. The cyclic substituents are preferably
35 C₃₋₈-cycloalkyl groups or C₅₋₁₀-aryl or heteroaryl
radicals, e.g. phenyl or naphthyl radicals, which may
have at least one substituent selected from halogen,
i.e. -F, -Cl, -Br or -I, -OH, -NO₂, -CN, -CH₃, -OCH₃ and
-CF₃.

R^2 is preferably H or $-CH_3$. At least one of R^3 and R^4 is preferably halogen, i.e. $-F$, $-Cl$, $-Br$ or $-I$. R^3 and R^4 are particularly preferably halogen, e.g. $-Cl$.

5

The invention further relates to physiologically tolerated salts of the compounds of formula 1.

10 The physiologically tolerated salts are obtained in a conventional way by neutralizing the bases with inorganic or organic acids or by neutralizing the acids with inorganic or organic bases. Examples of suitable inorganic acids are hydrochloric acid, sulfuric acid, phosphoric acid or hydrobromic acid, and examples of
15 suitable organic acids are carboxylic or sulfonic acids, such as acetic acid, tartaric acid, lactic acid, propionic acid, glycolic acid, malonic acid, maleic acid, fumaric acid, tannic acid, succinic acid, alginic acid, benzoic acid, 2-phenoxybenzoic acid, 2-
20 acetoxymethylbenzoic acid, cinnamic acid, mandelic acid, citric acid, malic acid, salicylic acid, 3-aminosalicylic acid, ascorbic acid, embonic acid, nicotinic acid, isonicotinic acid, oxalic acid, amino acids, methanesulfonic acid, ethanesulfonic acid, 2-
25 hydroxyethanesulfonic acid, ethane-1,2-disulfonic acid, benzenesulfonic acid, 4-methylbenzenesulfonic acid or naphthalene-2-sulfonic acid. Examples of suitable inorganic bases are sodium hydroxide solution, potassium hydroxide solution, ammonia, and suitable
30 organic bases are amines, but preferably tertiary amines such as trimethylamine, triethylamine, pyridine, N,N-dimethylaniline, quinoline, isoquinoline, α -picoline, β -picoline, γ -picoline, quinaldine or pyrimidine.

35

Physiologically tolerated salts of the compounds of formula 1 can additionally be obtained by converting derivatives having tertiary amino groups in a manner known per se with quaternizing agents into the

corresponding quaternary ammonium salts. Examples of suitable quaternizing agents are alkyl halides such as methyl iodide, ethyl bromide and n-propyl chloride, but also arylalkyl halides such as benzyl chloride or 2-phenylethyl bromide.

The invention further relates to the D form, the L form and D,L mixtures of compounds of the formula 1 which contain an asymmetric carbon atom, and in the case of a plurality of asymmetric carbon atoms, also the diastereomeric forms. Compounds of the formula 1 which contain asymmetric carbon atoms and usually result as racemates can be separated into the optically active isomers in a manner known per se, for example with an optically active acid. However, it is also possible to employ an optically active starting substance from the outset, in which case a corresponding optically active or diastereomeric compound is obtained as final product.

The compounds of the invention have been found to have pharmacologically important properties which can be utilized in therapy. The compounds of formula 1 can be employed alone, in combination with one another or in combination with other active ingredients.

The compounds of the invention are inhibitors of phosphodiesterase 4. It is therefore an aspect of this invention that the compounds of formula 1 and the salts thereof, and pharmaceutical preparations which comprise these compounds or salts thereof, can be used for the treatment of disorders in which inhibition of phosphodiesterase 4 is beneficial.

These disorders include, for example, inflammations of joints, including arthritis and rheumatoid arthritis, and other arthritic disorders such as rheumatoid spondylitis and osteoarthritis. Further possible uses are the treatment of patients suffering from

osteoporosis, sepsis, septic shock, Gram-negative sepsis, toxic shock syndrome, respiratory distress syndrome, asthma or other chronic pulmonary disorders, bone resorption disorders or transplant rejection
5 reactions or other autoimmune diseases such as lupus erythematosus, multiple sclerosis, glomerulonephritis and uveitis, insulin-dependent diabetes mellitus and chronic demyelination.

10 The compounds of the invention can additionally be employed for the therapy of infections such as viral infections and parasitic infections, for example for the therapy of malaria, leishmaniasis, infection-related fever, infection-related muscle pain, AIDS and
15 cachexia, and of non-allergic rhinitis.

The compounds of the invention can likewise be used for the therapy of hyperproliferative disorders, in particular of cancers, for example for the therapy of
20 melanomas, of breast cancer, lung cancer, bowel cancer, skin cancer and of leukemias.

The compounds of the invention can also be employed as bronchodilators and for the treatment of asthma, e.g.
25 for asthma prophylaxis.

The compounds of formula 1 are in addition inhibitors of the accumulation of eosinophils and the activity thereof. Accordingly, the compounds of the invention
30 can also be employed for disorders in which eosinophils are involved. These disorders include, for example, inflammatory respiratory tract disorders such as bronchial asthma, allergic rhinitis, allergic conjunctivitis, atopic dermatitis, eczemas, allergic
35 angiitis, eosinophil-mediated inflammations such as eosinophilic fasciitis, eosinophilic pneumonia and PIE syndrome (pulmonary infiltration with eosinophilia), urticaria, ulcerative colitis, Crohn's disease and

proliferative skin disorders such as psoriasis or keratosis.

5 It is an aspect of this invention that the compounds of formula 1 and salts thereof are also able to inhibit LPS-induced pulmonary neutrophilic infiltration in rats *in vivo*. The pharmacologically significant properties which have been found prove that the compounds of formula 1 and salts thereof, and pharmaceutical
10 preparations which comprise these compounds or salts thereof, can be utilized therapeutically for the treatment of chronic obstructive pulmonary diseases.

15 The compounds of the invention additionally have neuroprotective properties and can be used for the therapy of diseases in which neuroprotection is beneficial. Examples of such disorders are senile dementia (Alzheimer's disease), memory loss, Parkinson's disease, depression, strokes and
20 intermittent claudication.

Further possible uses of the compounds of the invention are the prophylaxis and therapy of prostate disorders such as, for example, benign prostate hyperplasia,
25 polyuria, nocturia, and the treatment of incontinence, of colic induced by urinary calculi, and of male and female sexual dysfunctions.

30 Finally, the compounds of the invention can likewise be used to inhibit the development of drug dependence on repeated use of analgesics such as, for example, morphine, and to reduce the development of tolerance on repeated use of these analgesics.

35 The drug products are produced by using an effective dose of the compounds of the invention or salts thereof, in addition to conventional adjuvants, carriers and additives. The dosage of the active ingredients may vary depending on the route of

administration, age and weight of the patient, nature and severity of the disorders to be treated and similar factors. The daily dose may be given as a single dose to be administered once a day, or divided into 2 or
5 more daily doses, and is usually 0.001-100 mg. Daily dosages of 0.1-50 mg are particularly preferably administered.

Oral, parenteral, intravenous, transdermal, topical,
10 inhalational and intranasal preparations are suitable as administration form. Topical, inhalational and intranasal preparations of the compounds of the invention are particularly preferably used. Galenical
15 pharmaceutical presentations such as tablets, coated tablets, capsules, dispersible powders, granules, aqueous solutions, aqueous or oily suspensions, syrup, solutions or drops are used.

Solid drug forms may comprise inert ingredients and
20 carriers such as, for example, calcium carbonate, calcium phosphate, sodium phosphate, lactose, starch, mannitol, alginates, gelatin, guar gum, magnesium stearate or aluminum stearate, methylcellulose, talc, colloidal silicas, silicone oil, high molecular weight
25 fatty acids (such as stearic acid), agar-agar or vegetable or animal fats and oils, solid high molecular weight polymers (such as polyethylene glycol); preparations suitable for oral administration may, if desired, comprise additional flavorings and/or
30 sweeteners.

Liquid drug forms can be sterilized and/or where appropriate comprise excipients such as preservatives, stabilizers, wetting agents, penetrants, emulsifiers,
35 spreading agents, solubilizers, salts, sugars or sugar alcohols to control the osmotic pressure or for buffering and/or viscosity regulators.

Examples of such additions are tartrate buffer and citrate buffer, ethanol, complexing agents (such as ethylenediaminetetraacetic acid and its non-toxic salts). Suitable for controlling the viscosity are high
5 molecular weight polymers such as, for example, liquid polyethylene oxide, microcrystalline celluloses, carboxymethylcelluloses, polyvinylpyrrolidones, dextrans or gelatin. Examples of solid carriers are starch, lactose, mannitol, methylcellulose, talc,
10 colloidal silicas, higher molecular weight fatty acids (such as stearic acid), gelatin, agar-agar, calcium phosphate, magnesium stearate, animal and vegetable fats, solid high molecular weight polymers such as polyethylene glycol.

15 Oily suspensions for parenteral or topical uses may be vegetable synthetic or semisynthetic oils such as, for example, liquid fatty acid esters with in each case 8 to 22 C atoms in the fatty acid chains, for example
20 palmitic, lauric, tridecylic, margaric, stearic, arachic, myristic, behenic, pentadecylic, linoleic, elaidic, brasidic, erucic or oleic acid, which are esterified with monohydric to trihydric alcohols having 1 to 6 C atoms, such as, for example, methanol,
25 ethanol, propanol, butanol, pentanol or isomers thereof, glycol or glycerol. Examples of such fatty acid esters are commercially available miglyols, isopropyl myristate, isopropyl palmitate, isopropyl stearate, PEG 6-capric acid, caprylic/capric esters of
30 saturated fatty alcohols, polyoxyethylene glycerol trioleates, ethyl oleate, waxy fatty acid esters such as artificial duck preen gland fat, coco fatty acid isopropyl ester, oleyl oleate, decyl oleate, ethyl lactate, dibutyl phthalate, diisopropyl adipate, polyol
35 fatty acid esters inter alia. Likewise suitable are silicone oils differing in viscosity or fatty alcohols such as isotridecyl alcohol, 2-octyldodecanol, cetylstearyl alcohol or oleyl alcohol, fatty acids such as, for example, oleic acid. It is additionally

possible to use vegetable oils such as castor oil, almond oil, olive oil, sesame oil, cottonseed oil, peanut oil or soybean oil.

- 5 Suitable solvents, gel formers and solubilizers are water or water-miscible solvents. Suitable examples are alcohols such as, for example, ethanol or isopropyl alcohol, benzyl alcohol, 2-octyldodecanol, polyethylene glycols, phthalates, adipates, propylene glycol, glycerol, di- or tripropylene glycol, waxes, methyl Cellosolve, Cellosolve, esters, morpholines, dioxane, dimethyl sulfoxide, dimethylformamide, tetrahydrofuran, cyclohexanone etc.
- 10
- 15 Film formers which can be used are cellulose ethers able to dissolve or swell both in water and in organic solvents, such as, for example, hydroxypropylmethylcellulose, methylcellulose, ethylcellulose or soluble starches.
- 20
- Combined forms of gel formers and film formers are likewise perfectly possible. Ionic macromolecules are used in particular for this purpose, such as, for example, sodium carboxymethylcellulose, polyacrylic acid, polymethacrylic acid and salts thereof, sodium amylopectin semiglycolate, alginic acid or propylene glycol alginate as sodium salt, gum arabic, xanthan gum, guar gum or carrageenan.
- 25
- 30 Further formulation aids which can be employed are: glycerol, paraffin of differing viscosity, triethanolamine, collagen, allantoin, novantisolic acid.
- 35
- It may also be necessary to use surfactants, emulsifiers or wetting agents for the formulation, such as, for example, Na lauryl sulfate, fatty alcohol ether sulfates, di-Na-N-lauryl- β -iminodipropionate, polyethoxylated castor oil or sorbitan monooleate,

sorbitan monostearate, polysorbates (e.g. Tween), cetyl alcohol, lecithin, glyceryl monostearate, polyoxyethylene stearate, alkylphenol polyglycol ether, cetyltrimethylammonium chloride or
5 mono/dialkylpolyglycol ether orthophosphoric acid monoethanolamine salts.

Stabilizers such as montmorillonites or colloidal silicas to stabilize emulsions or to prevent
10 degradation of the active substances, such as antioxidants, for example tocopherols or butylated hydroxyanisole, or preservatives such as p-hydroxybenzoic esters, may likewise be necessary where appropriate to prepare the desired formulations.

15 Preparations for parenteral administration may be present in separate dose unit forms such as, for example, ampoules or vials. Solutions of the active ingredient are preferably used, preferably aqueous
20 solutions and especially isotonic solutions, but also suspensions. These injection forms can be made available as finished product or be prepared only immediately before use by mixing the active compound, e.g. the lyophilisate, where appropriate with further
25 solid carriers, with the desired solvent or suspending agent.

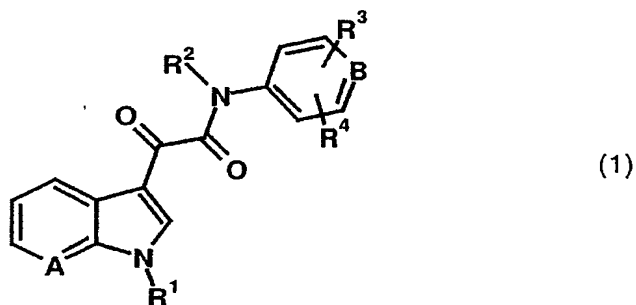
Intranasal preparations may be in the form of aqueous or oily solutions or of aqueous or oily suspensions.
30 They may also be in the form of lyophilisates which are prepared before use with the suitable solvent or suspending agent.

The manufacture, bottling and closure of the products
35 takes place under the usual antimicrobial and aseptic conditions.

The invention further relates to processes for preparing the compounds of the invention.

The compounds of the general formula 1 with the meanings of A, B, R¹, R², R³ and R⁴ described above are prepared according to the invention

5



by oxidizing compounds of the formula 1 with the meaning of R¹, R², R³ and R⁴ described above, in which A is nitrogen and B may be nitrogen or carbon, in a manner known per se by treatment with an oxidizing agent, e.g. an organic peracid, preferably with m-chloroperbenzoic acid or/and peracetic acid, to the compounds of the invention of the formula 1a, 1b or 1c.
15 Mixtures of N-oxides which result where appropriate can be separated in a manner known per se by crystallization or chromatographic methods into the pure compounds of the formula 1a, 1b or 1c.

20 Examples

Example 1:

Exemplary process for preparing compounds of the invention of the formula 1a:

25

1.1 N-(3,5-Dichloropyridin-4-yl)-[1-(4-fluorobenzyl)-7-oxo-7-aza-1,3-dihydroindol-3-yl]glyoxylamide

3 g of N-(3,5-dichloropyridin-4-yl)-[1-(4-fluorobenzyl)-7-oxo-7-aza-1,3-dihydroindol-3-yl]glyoxylamide are dissolved in 180 ml of dichloromethane. While stirring, a solution of 6 g of m-chloroperbenzoic acid in 12 ml

of acetic acid is added dropwise. The reaction mixture is stirred at room temperature for 7 days. The mixture is adjusted to pH 8 to 9 by adding a potassium carbonate solution. The phases are separated, and the
5 organic phase is washed with 100 ml of water. The solvent is distilled out in vacuo. The residue is stirred with 10 ml of isopropanol. The crystals are removed and dried at room temperature. The crude product is purified by preparative HPLC. A mixture of
10 ethyl acetate with methanol in the ratio 85:15 is used as solvent system.

The solvent mixture is distilled from the product-containing fraction in vacuo, and the residue is
15 recrystallized from isopropanol.

Yield: 0.3 g (9.4% of theory)

Melting point: 205-208°C

20 **1.2 N-(2,6-Dichlorophenyl)-[1-(2-chlorobenzyl)-7-oxo-7-azaindol-3-yl]glyoxylamide**

3.1 g of N-(3,5-dichlorophenyl)-[1-(2-chlorobenzyl)-7-azaindol-3-yl]glyoxylamide are dissolved in 180 ml of
25 dichloromethane. While stirring, a solution of 6 g of m-chloroperbenzoic acid in 12 ml of acetic acid is added dropwise. The reaction mixture is stirred at room temperature for 7 days. The mixture is adjusted to pH 8 to 9 by adding a potassium carbonate solution. The
30 phases are separated, and the organic phase is washed with 100 ml of water. The solvent is distilled out in vacuo. The residue is stirred with 30 ml of water at 50 °C, filtered off with suction and recrystallized from 100 ml of isopropanol.

35

Yield: 1.3 g (40% of theory)

Melting point: 165-168°C

Example 2:

Exemplary process for preparing compounds of the invention of the formula 1b:

5 **2.1 N-(3,5-Dichloro-1-oxopyridin-4-yl)-[1-(4-fluorobenzyl)-7-azaindol-3-yl]glyoxylamide**

3 g of N-(3,5-dichloropyridin-4-yl)-[1-(4-fluorobenzyl)-7-azaindol-3-yl]glyoxylamide are
10 dissolved in 180 ml of dichloromethane. While stirring, a solution of 6 g of m-chloroperbenzoic acid in 12 ml of acetic acid is added dropwise. The reaction mixture is stirred at room temperature for 7 days. The mixture is adjusted to pH 8 to 9 by adding a potassium
15 carbonate solution. The phases are separated, and the organic phase is washed with 100 ml of water. The solvent is distilled out in vacuo. The residue is stirred with 10 ml of isopropanol. The crystals are removed and dried at room temperature. The crude
20 product is purified by preparative HPLC. A mixture of ethyl acetate with methanol in the ratio 85:15 is used as solvent system.

The solvent mixture is distilled from the product-
25 containing fraction in vacuo, and the residue is recrystallized from ethanol.

Yield: 1.2 g (37.5% of theory)

Melting point: 233-236°C

30

Example 3:

Exemplary process for preparing compounds of the invention of the formula 1c:

35 **3.1 N-(3,5-Dichloro-1-oxopyridin-4-yl)-[1-(4-fluorobenzyl)-7-oxo-7-azaindol-3-yl]glyoxylamide**

3 g of N-(3,5-dichloropyridin-4-yl)-[1-(4-fluorobenzyl)-7-azaindol-3-yl]glyoxylamide are

- dissolved in 180 ml of dichloromethane. While stirring, a solution of 6 g of m-chloroperbenzoic acid in 12 ml of acetic acid is added dropwise. The reaction mixture is stirred at room temperature for 7 days. The mixture is adjusted to pH 8 to 9 by adding a potassium carbonate solution. The phases are separated, and the organic phase is washed with 100 ml of water. The solvent is distilled out in vacuo. The residue is stirred with 10 ml of isopropanol. The crystals are removed and dried at room temperature. The crude product is purified by preparative HPLC. A mixture of ethyl acetate with methanol in the ratio 90:10 is used as solvent system.
- The solvent mixture is distilled from the product-containing fraction in vacuo, and the residue is recrystallized from ethanol.

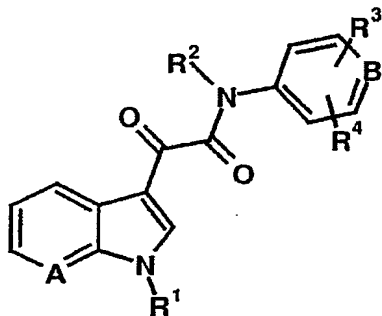
Yield: 0.2 g (6.3% of theory)

- Melting point: 254-257°C

Example 4:

Preparation of further compounds

- Numerous further compounds of the formula 1 can be prepared by using the indicated processes for preparation, of which the following are cited as examples:



(1)

Compound	A	B	R ¹	-R ²	-R ³	-R ⁴
1	N-O	N	4-Fluorobenzyl-	-H	-Cl	-Cl
2	N-O	CH	2-Chlorobenzyl-	-H	-Cl	-Cl
3	N	N-O	4-Fluorobenzyl-	-H	-Cl	-Cl
4	N-O	N-O	4-Fluorobenzyl-	-H	-Cl	-Cl
5	N-O	CH	4-Fluorobenzyl-	-H	-H	-H
6	N	N-O	2-Fluorobenzyl-	-H	-Cl	-Cl
7	N	N-O	3-Nitrobenzyl-	-H	-Cl	-Cl
8	N	N-O	2,6-Difluorobenzyl-	-H	-Cl	-Cl
9	N	N-O	2,4-Dichlorobenzyl-	-H	-Cl	-Cl
10	N-O	N	2,4-Dichlorobenzyl-	-H	-Cl	-Cl
11	N	N-O	2-Chlorobenzyl-	-H	-Cl	-Cl
12	N-O	N	2-Chlorobenzyl-	-H	-Cl	-Cl
13	N-O	N-O	2-Chlorobenzyl-	-H	-Cl	-Cl
14	N-O	N	2-Chlorobenzyl-	-CH ₃	-Cl	-Cl
15	N	N-O	2-Chlorobenzyl-	-CH ₃	-Cl	-Cl
16	N	N-O	2-Chlorobenzyl-	-CH ₃	-H	-H
17	N	N-O	2,6-Dichlorobenzyl-	-H	-Cl	-Cl
18	N	N-O	2-Methylbenzyl-	-H	-Cl	-Cl
19	N	N-O	2,6-Dimethylbenzyl-	-H	-Cl	-Cl
20	N	N-O	n-Hexyl-	-H	-Cl	-Cl
21	N	N-O	Isobutyl-	-H	-Cl	-Cl
22	N	N-O	Cyclopropylmethyl-	-H	-Cl	-Cl
23	N	N-O	1-Naphthylmethyl-	-H	-Cl	-Cl
24	N-O	N	2-Chloro-6-fluorobenzyl-	-H	-Cl	-Cl
25	N	N-O	2-Chloro-6-fluorobenzyl-	-H	-Cl	-Cl
26	N-O	N-O	2-Chloro-6-fluorobenzyl-	-H	-Cl	-Cl
27	N	N-O	2-Difluoromethoxybenzyl-	-H	-Cl	-Cl
28	N	N-O	2-Cyanobenzyl-	-H	-Cl	-Cl

The compounds of the invention are strong inhibitors of phosphodiesterase 4. Their therapeutic potential is demonstrated *in vivo* for example through the inhibition of the asthmatic late-phase reaction (eosinophilia) and

through the inhibition of LPS-induced neutrophilia in rats.

Example 5:

5 Phosphodiesterase 4 inhibition

PDE4 activity is determined using enzyme preparations from human polymorphonuclear lymphocytes (PMNL). Human blood (buffy coats) was anticoagulated with citrate. A centrifugation at 700 x g at room temperature (RT) for 20 minutes separates the platelet-rich plasma in the supernatant from the erythrocytes and leukocytes. The PMNLs for the PDE4 determination are isolated by a subsequent dextran sedimentation and in gradient centrifugation with Ficoll-Paque. After the cells have been washed twice, the erythrocytes which are still present are lysed by adding 10 ml of hypotonic buffer (155 mM NH₄Cl, 10 mM NaHCO₃, 0.1 mM EDTA, pH=7.4) at 4°C within 6 minutes. The still intact PMNLs are then washed twice with PBS and lysed by ultrasound. The supernatant from a centrifugation at 4°C and 48000 x g for one hour contains the cytosolic fraction of PDE 4 and is employed for the PDE4 measurements.

The phosphodiesterase activity is assayed using a modified Amersham Pharmacia Biotech method, an SPA (scintillation proximity assay).

The reaction mixtures contain buffer (50 mM Tris-HCl (pH 7.4), 5 mM MgCl₂, 100 µM cGMP), the inhibitors in variable concentrations and the appropriate enzyme preparation. The reaction is started by adding the substrate, 0.5 µM [³H]-cAMP. The final volume is 100 µl. Test substances are made up as stock solutions in DMSO. The DMSO concentration in the reaction mixture is 1% v/v. The PDE activity is unaffected at this DMSO concentration. After the reaction has been started by adding substrate, the samples are incubated at 37°C for 30 minutes. The reaction is stopped by adding a defined

amount of SPA beads, and the samples are counted after one hour in a Beta counter. The nonspecific enzymic activity (the blank) is determined in the presence of 100 μ M rolipram and subtracted from the test results.

- 5 The incubation mixtures for the PDE4 assay contain 100 μ M cGMP in order to inhibit any contamination by PDE 3.

10 The IC_{50} values for inhibition of phosphodiesterase 4 determined for the compounds of the invention were in the range from 10^{-10} to 10^{-5} M. The selectivity factor in relation to PDE of types 3, 5 and 7 is from 100 to 10.000.

- 15 The results of PDE4 inhibition for selected use examples are compiled by way of example in the following table:

Compound	PDE 4 inhibition
	IC_{50} [μ mol/l]
1	0.052
2	0.048
3	0.008
4	0.751

- 20 **Example 6:**

Inhibition of late-phase eosinophilia 48 h after inhalational ovalbumin challenge in actively sensitized brown Norway rats

- 25 Inhibition of the pulmonary eosinophilic infiltration by the substances of the invention is tested on male brown Norway rats (200-250 g) actively sensitized against ovalbumin (OVA). The sensitization takes place by subcutaneous injections of a suspension of 10 μ g of
30 OVA together with 20 mg of aluminum hydroxide as adjuvant in 0.5 ml of physiological saline per animal on day 1, 14 and 21. In addition to this, the animals receive at the same time i.p. injections of 0.25 ml of

Bordetella pertussis vaccine dilution per animal. On day 28 of the test, the animals are placed singly in open 1 l Plexiglas boxes connected to a head/nose exposure apparatus. The animals are exposed to an aerosol of 1.0% ovalbumin suspension (allergen challenge). The ovalbumin aerosol is generated by a nebulizer (Bird micro nebulizer, Palm Springs CA, USA) operated with compressed air (0.2 MPa). The exposure time is 1 hour, with an aerosol of 0.9% saline being nebulized for normal controls likewise for 1 hour.

48 hours after the allergen challenge there is a massive migration of eosinophilic granulocytes into the lungs of the animals. At this time, the animals are anesthetized with an overdose of ethylurethane (1.5 g/kg of body weight i.p.), and a bronchoalveolar lavage (BAL) is carried out with 3 x 4 ml of Hank's balanced solution. The total cell count and the number of eosinophilic granulocytes in the pooled BAL liquid are subsequently determined using an automatic cell differentiation instrument (Bayer Diagnostics Technicon H1E). The eosinophils (EOS) in the BAL are calculated for each animal in $10^6/\text{animal}$: $\text{EOS}/\mu\text{l} \times \text{BAL recovery (ml)} = \text{EOS/animal}$.

Two control groups (nebulization of physiological saline and nebulization of OVA solution) are included in each test.

The percentage inhibition of the eosinophilia in the test group treated with the substance is calculated by the following formula:

$$\{((\text{OVAC} - \text{SC}) - (\text{OVAD} - \text{SC})) / (\text{OVAC} - \text{SC})\} \times 100\% = \%$$

% inhibition

(SC = control group treated with vehicle and challenged with 0.9% saline; OVAC = control group treated with vehicle and challenged with 1% ovalbumin suspension;

OVAD = test group treated with substance and challenged with 1% ovalbumin suspension)

5 The test substances are administered intraperitoneally or orally as suspension in 10% polyethylene glycol 300 and 0.5% 5-hydroxyethylcellulose 2 hours before the allergen challenge. The control groups are treated with the vehicle in accordance with the test substance application form.

10

The compounds of the invention inhibit the late-phase eosinophilia by 30% to 100% after intraperitoneal administration of 10 mg/kg and by 30% to 80% after oral administration of 30 mg/kg.

15

The compounds of the invention are thus particularly suitable for producing drug products for the treatment of disorders associated with the effect of eosinophils.

20

Example 7:

Inhibition of lipopolysaccharide (LPS)-induced pulmonary neutrophilia in Lewis rats

25

The inhibition of pulmonary neutrophil infiltration by the substances of the invention is tested on male Lewis rats (250-350 g). On the day of the test, the animals are placed singly in open 1 l Plexiglas boxes connected to a head/nose exposure apparatus. The animals are exposed to an aerosol from a lipopolysaccharide suspension (100 µg of LPS/ml of 0.1% hydroxylamine solution) in PBS (LSP provocation). The LPS/hydroxylamine aerosol is generated by a nebulizer (Bird micro nebulizer, Palm Springs CA, USA) operated by compressed air (0.2 MPa). The exposure time is 40 minutes, with an aerosol being nebulized from 0.1% hydroxylamine solution in PBS for normal controls, likewise for 40 minutes.

35

6 hours after the LPS provocation there is a maximal, massive migration of neutrophilic granulocytes into the lungs of the animals. At this time, the animals are anesthetized with an overdose of ethylurethane (1.5 g/kg of body weight i.p.), and a bronchoalveolar lavage (BAL) is carried out with 3 x 4 ml of Hank's balanced solution. The total cell count and the number of neutrophilic granulocytes in the pooled BAL liquid are subsequently determined using an automatic cell differentiation apparatus (Bayer Diagnostics Technicon H1E). The neutrophils (NEUTRO) in the BAL are calculated for each animal in $10^6/\text{animal}$: $\text{NEUTRO}/\mu\text{l} \times \text{BAL recovery (ml)} = \text{NEUTRO}/\text{animal}$.

Two control groups (nebulization of 0.1% hydroxylamine solution in PBS and nebulization of 100 μg of LPS/ml of 0.1% hydroxylamine solution in PBS) are included in each test.

The percentage inhibition of the neutrophilia in the test group treated with the substance is calculated by the following formula:

$$\{((\text{LPSC} - \text{SC}) - (\text{LPSD} - \text{SC})) / (\text{LPSC} - \text{SC})\} \times 100\% = \text{\% inhibition}$$

SC = control group treated with vehicle and challenged with 0.1% hydroxylamine solution; LPSC = control group treated with vehicle and challenged with LPS (100 $\mu\text{g}/\text{ml}$ of 0.1% hydroxylamine solution); LPSD = test group treated with substance and challenged with LPS (100 $\mu\text{g}/\text{ml}$ of 0.1% hydroxylamine solution).

The test substances are administered orally as suspension in 10% polyethylene glycol 300 and 0.5% 5-hydroxyethylcellulose 2 hours before the LPS provocation. The control groups are treated with the vehicle in accordance with the test substance administration form.

The compounds of the invention inhibit the neutrophilia by 30% to 90% after oral administration of 1 mg/kg and are thus particularly suitable for producing drug
5 products for the treatment of disorders associated with the effect of neutrophils.